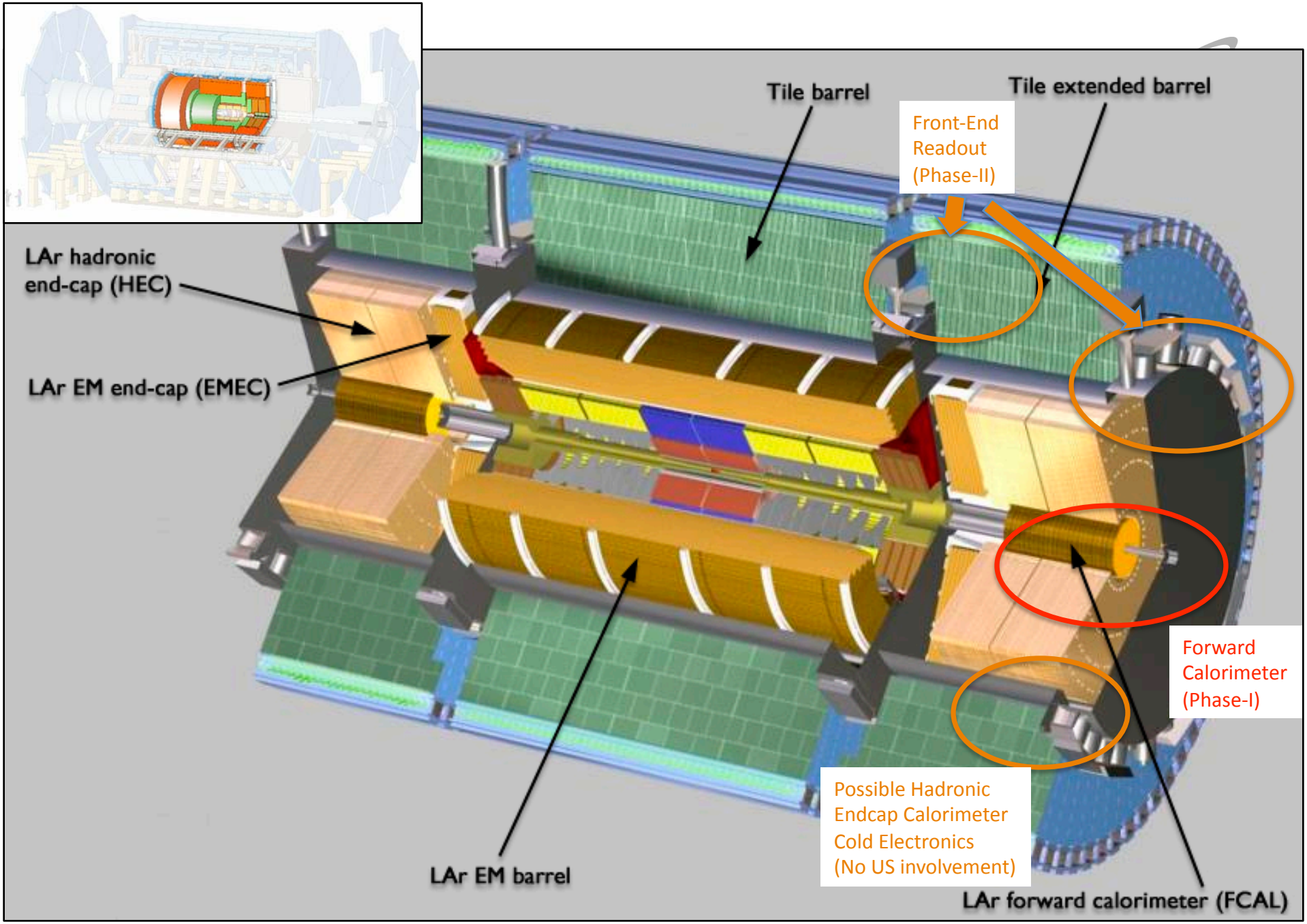
LAr FCAL Upgrade Plans

F. Lanni
Brookhaven National Laboratory

Outline

- The Atlas Calorimeter System
- General Atlas LAr Upgrade organization and plans (phase-I and II)
  - Readout Electronics
  - Cryogenic Front-End for the HadronicEndcap calorimeter
  - Engineering Studies
- FCAL issues @ sLHC upgrade
- Options for a new FCAL
- Toward an FCAL Upgrade Construction Project


Tile barrel
Tile extended barrel
Front-End
Readout
(Phase-II)
LAr hadronic
end-cap (HEC)
LAr EM end-cap (EMEC)
Forward
Calorimeter
(Phase-I)
Possible Hadronic
Endcap Calorimeter
Cold Electronics
(No US involvement)
LAr EM barrel
LAr forward calorimeter (FCAL)

LAr Upgrade Organization and Plans

BROOKHAVEN NATIONAL LABORATORY

Atlas Upgrade Steering Group (N. Hessey)

Atlas Upgrade Project Office (D. Lissauer)

LAr Mgmt/PL (I. Wingerter-Seez)

LAr Upgrade R&D (F. Lanni, C. Zeitnitz)

Detector Studies

Engineering and detail design studies need to start now.

FCAL Replacement
U. Arizona

High Voltage
Detector Geo.
Cooling

HEC Upgrade

Cold Elec.
Upgrade

Eng. Studies

Access
Schedule
Activation
Tooling
Cooling/Cryo

Warm MiniCal

Det. Tech.
Integration

On going R&D.

Readout Architecture System Integration

Integration (after 2010)

Front-End
BNL
Columbia/Nevis
U. Penn.

Analog SiGe FE
- Preamplifier
- Shaper
Gain Selection
ADC
DataFlow/
Compression
Configuration

Optical Data Transmission
SMU

L1/TDAQ Interface

Other Boards
Calib
TBB
Controller

HEC Cold Preamplfiers

PS System
BNL

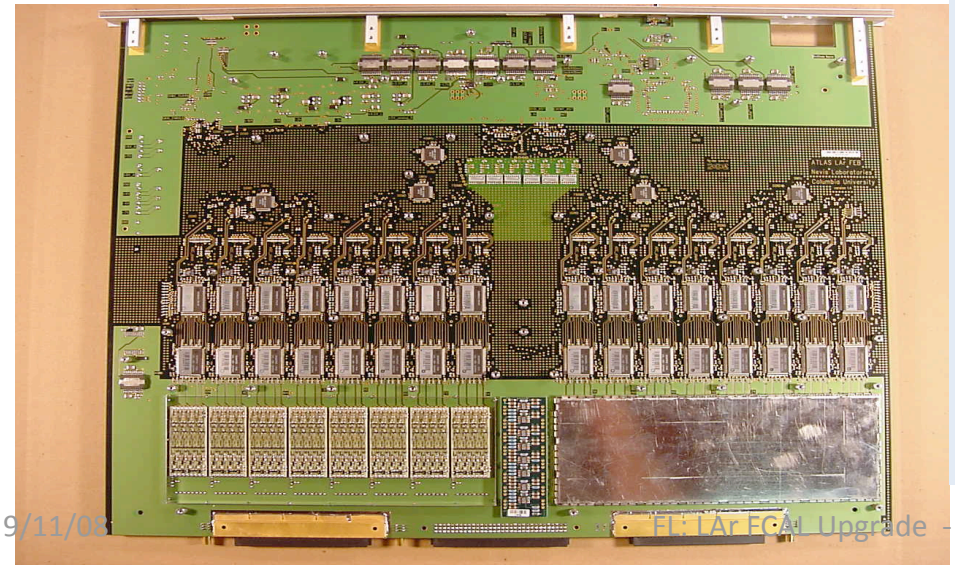
ROD/Back End
BNL
U. Arizona

Readout Electronics Upgrade Plans

10 years @ 10^{34}

Radiation Type	*Simulated Level*	*Safety Factors*			*Total Radiation Tolerance Criterion*	*3 -years @ sLHC*
		Simulation	*Low Dose Rate*	*Lot Variations*		
Total Ionizing Dose	*5 kRad*	*3.5*	*5*	*2*	*175 kRad*	*525 kRad*
Neutron Fluence	*1.6 x 10^{12} n/ cm^2*	*5*	*1*	*2*	*1.6 x 10^{13} n/ cm^2*	*4.8 x 10^{13} n/ cm^2*
Single Event Upsets	*7.7 x 10^{11} h/ cm^2*	*5*	*1*	*2*	*7.7 x 10^{12} h/ cm^2*	*2.3 x 10^{13} h/ cm^2*

Phase-II upgrade needed because of radiation level issues of board components



1) Components can not replaced as the technology will not be available.
2) Limited numbers of spares available.
3) Qualification for radiation tolerance is 10yrs at nominal luminosity.
4) Therefore replacement is required for sLHC..
5) May be replacement will be needed is failure rate is higher than expected?
6) Phase-II …

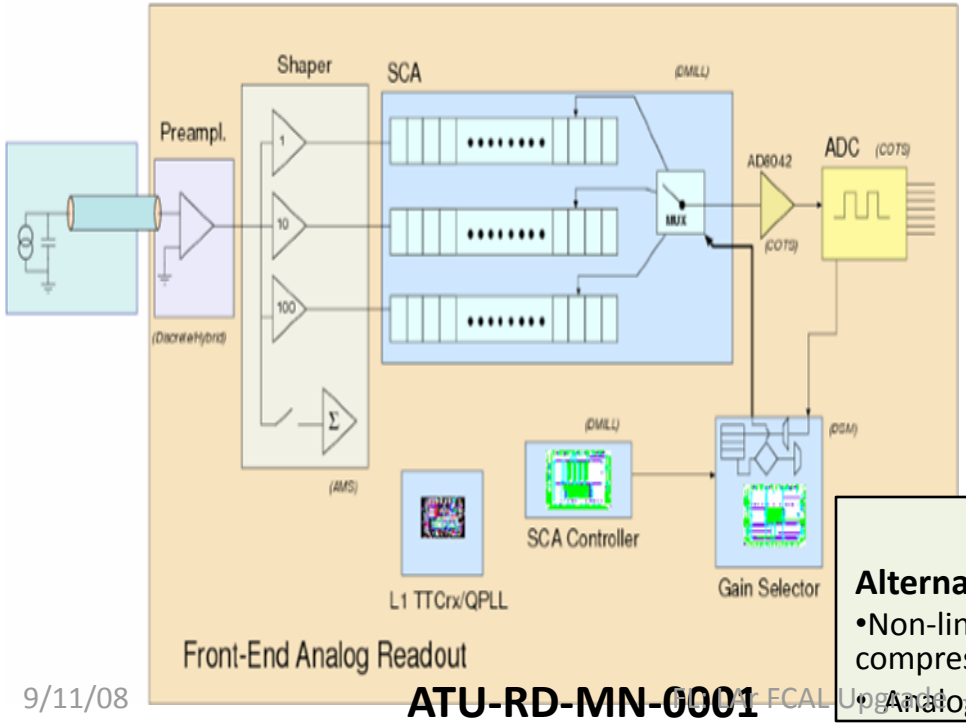
Readout Electronics Upgrade

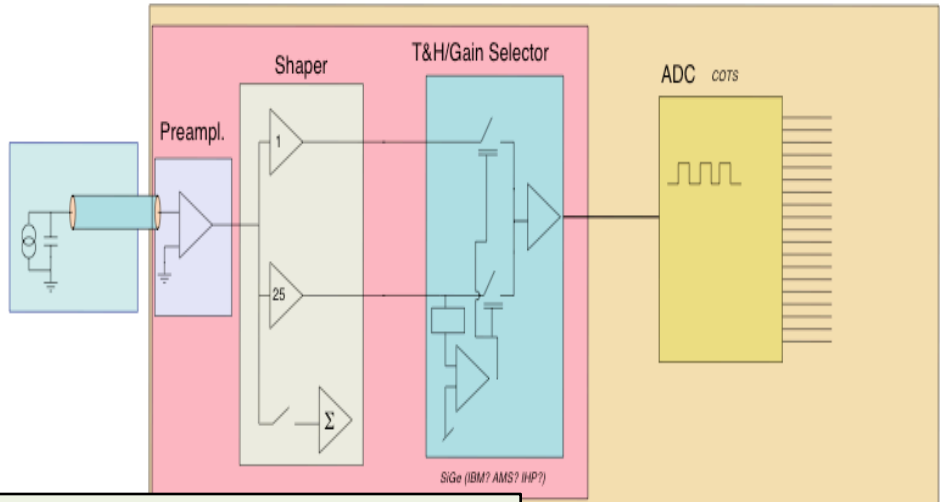
Current Implementation:

- 3 Gain Settings (x1,x10,x100)
- Analog Pipeline (2.5μs)
- L1 receiver (100kHz max. trigger rate)
- Gain Selector mechanism and digitization upon receipt of the L1 signal

Baseline for sLHC:

- 2 Gain Settings?
- Pipeline off-detector. 40MSPS digitization
  - Data throughput: 100 Gbps/board
  - Radiation hardened FPGA and data lossless compression (100->30Gbps)?
- Analog T&H?
- How much integration on a single ASIC ?





Alternative Design and R&D studies:

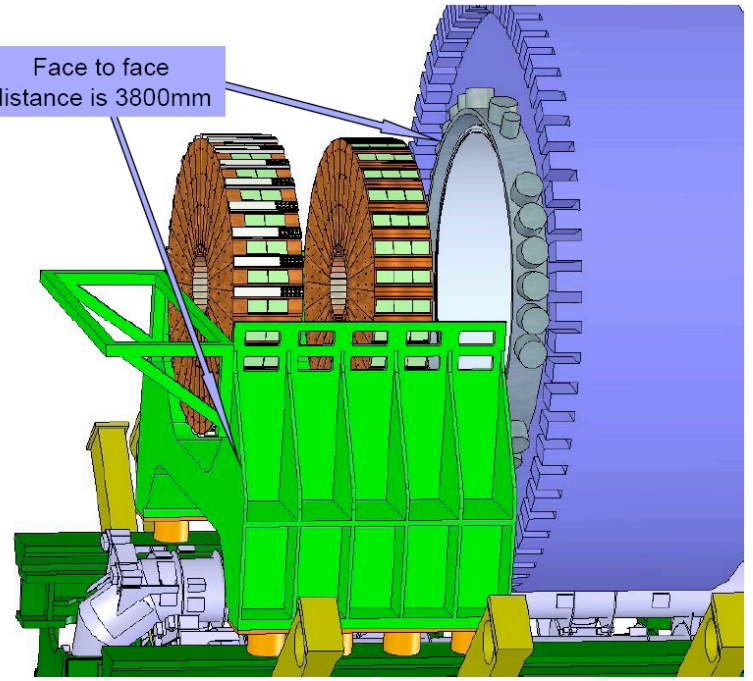
- Non-linear preamplifier? Signal dynamic compression
- Analog Optical Transmission

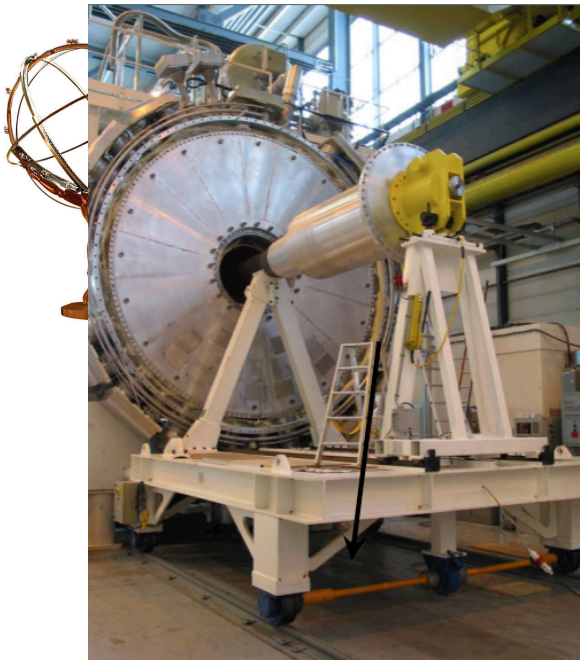
BEWARE OF POWER BUDGET

Cryogenic Front-End for the Hadronic Endcap Calorimeter

- GaAs preamplifiers installed on detector
- Qualified for 10yrs operation at nominal luminosity
- R&D studies by MPI and German Universities to evaluate radiation tolerance above 10^34 …
- …as well as alternative technologies (cryogenic SiGe processes)

- Also (TRIUMF) tooldesign to access the calorimeter wheels for replacing the PC boards that house preamplifiers





(thanks to John Rutherfoord for his contributions)

BROOKHAVEN NATIONAL LABORATORY

FCAL2, FCAL3: HAD

Shielding Pug

FCAL1: EM

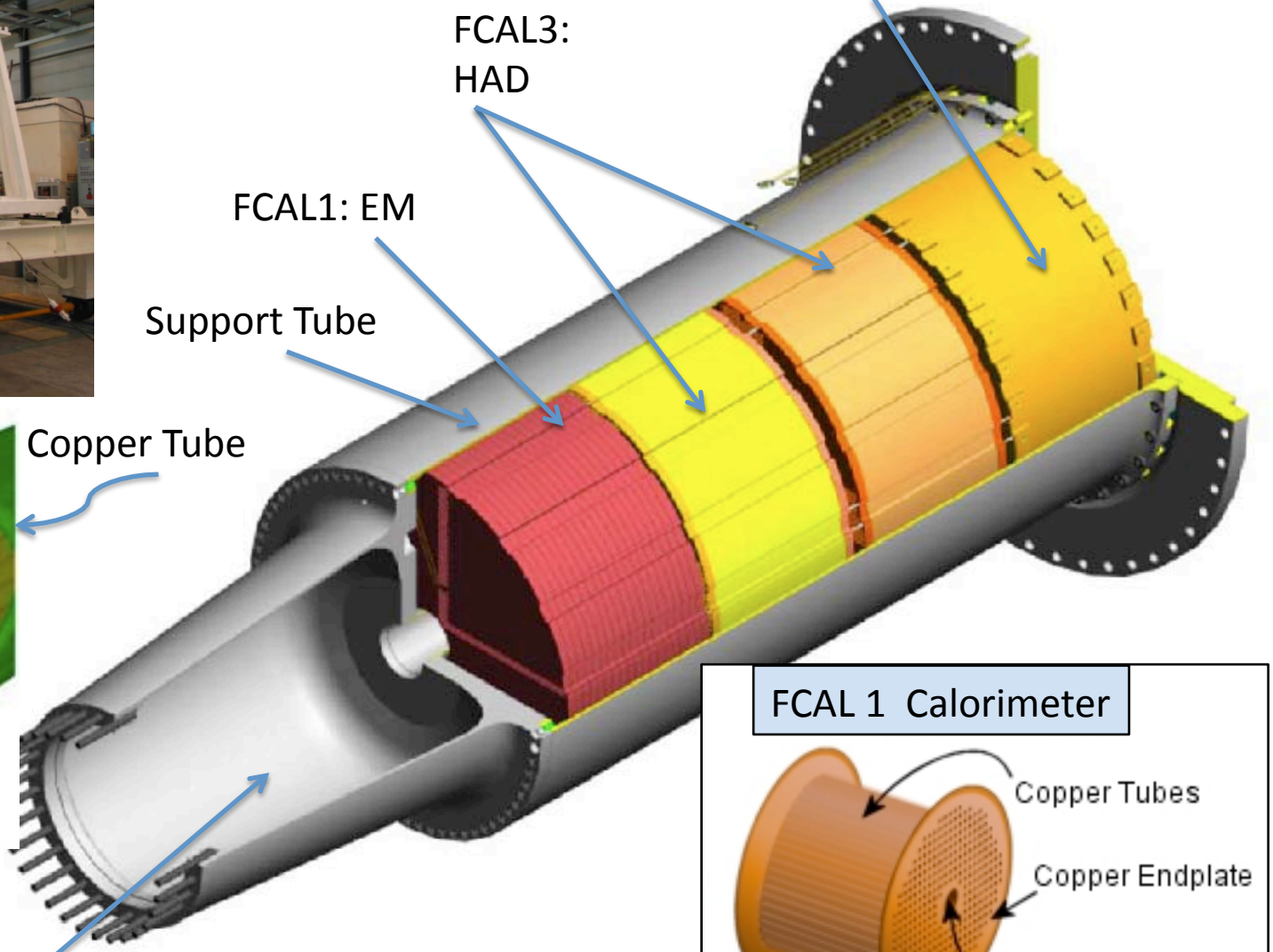
Support Tube

Copper Tube

Peek Fiber

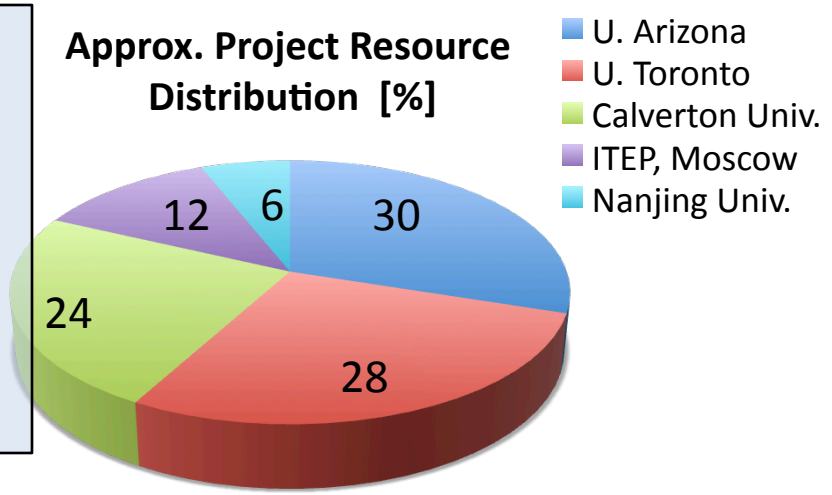
Copper Rod

Forward Cone



The FCAL Project

- The original construction project was a collaborative effort between 4 funding agencies.
- U.S Contribution: ~3.3M USD



US Contributions (U. of Arizona resp.):

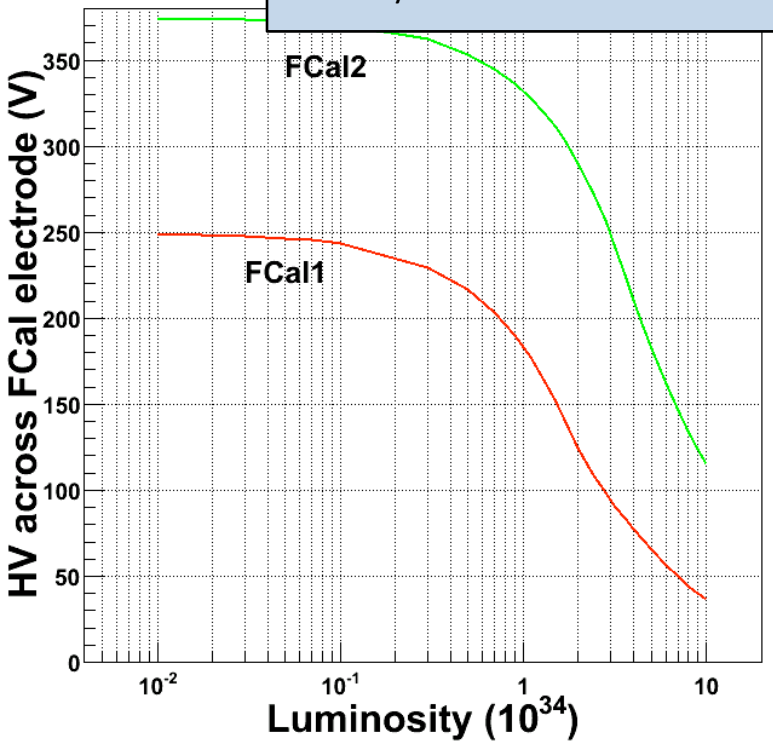
- Development and design (…novel readout geometry developed for the SSC GEM detector and adopted by Atlas in 1993)
- Deliverables:
  - FCAL1 (e.m. modules)
  - HV distribution and summing boards
  - Cold cables
  - Share of responsibility of final assembly and installation @ CERN
  - Stewardship responsibility for optimal integration of the FCAL assembly into ATLAS, including calibration and software development
- J. Rutherfoord, U. of Arizona, was the LAr-FCAL project leader within the Atlas LAr collaboration during the whole construction phase.

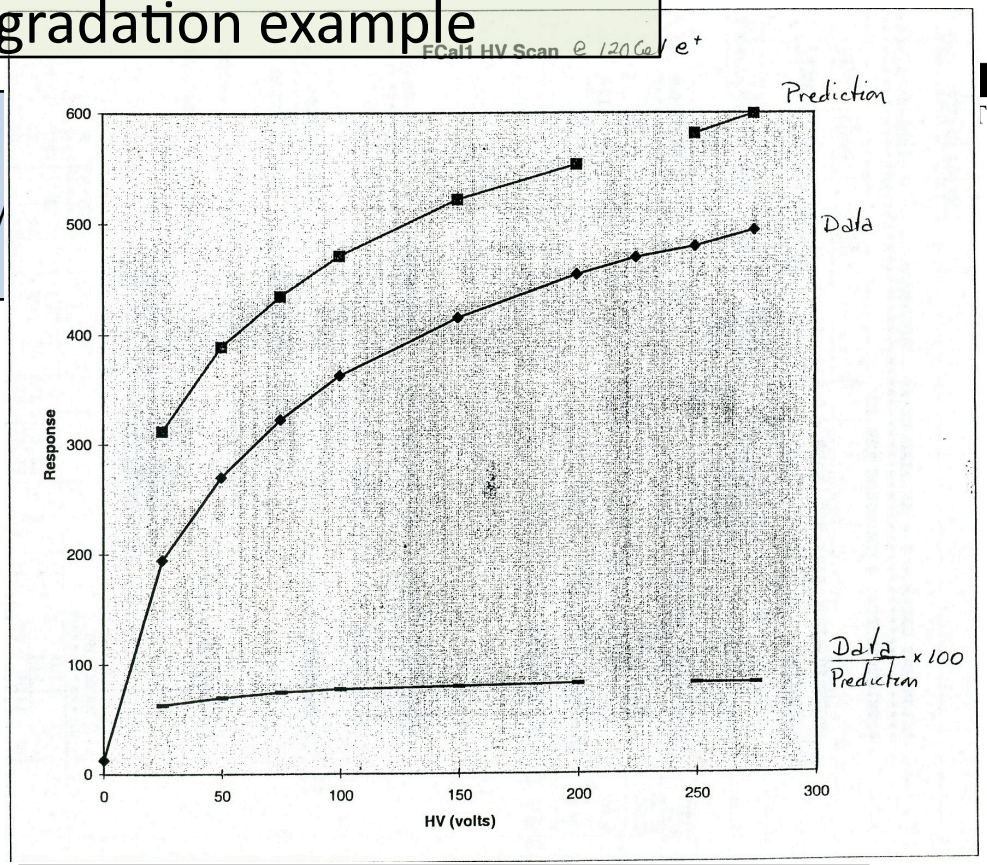
FCAL performance degradation

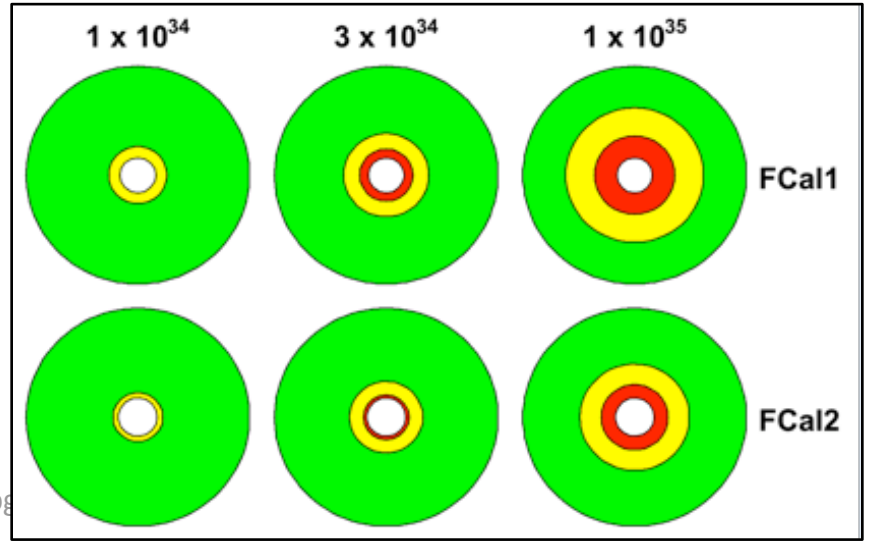
- Detector performance will deteriorate at luminosities above the nominal 10^{34}.
- The main issues are:
  - **Space charge effects arising from slowly drifting positive ion build-up**
  - **Heating by dE/dx of the FCAL modules with possible consequent boiling of Argon**
  - **Significant drop in the HV distribution that generates the drifting electric field in the detector elements.**
- In at least the latter case there is no enough margin at $3x10^{34}$ so the FCAL performance may degrade significantly.
- Calculations are based on MonteCarlo simulation of minimum bias events. There are uncertainties associated to the different generators
  - Data availability by end 2008/mid 2009 will allow more accurate estimates
- A complete assessment of the performance degradation has just begun and it is being pursued vigorously

Performance degradation example

Gradual degradation as luminosity increase above the nominal value
However at $3x10^{34}$ the HV drops already down by x2.5







Also the effects are strongly dependent on the radius (rapidity)

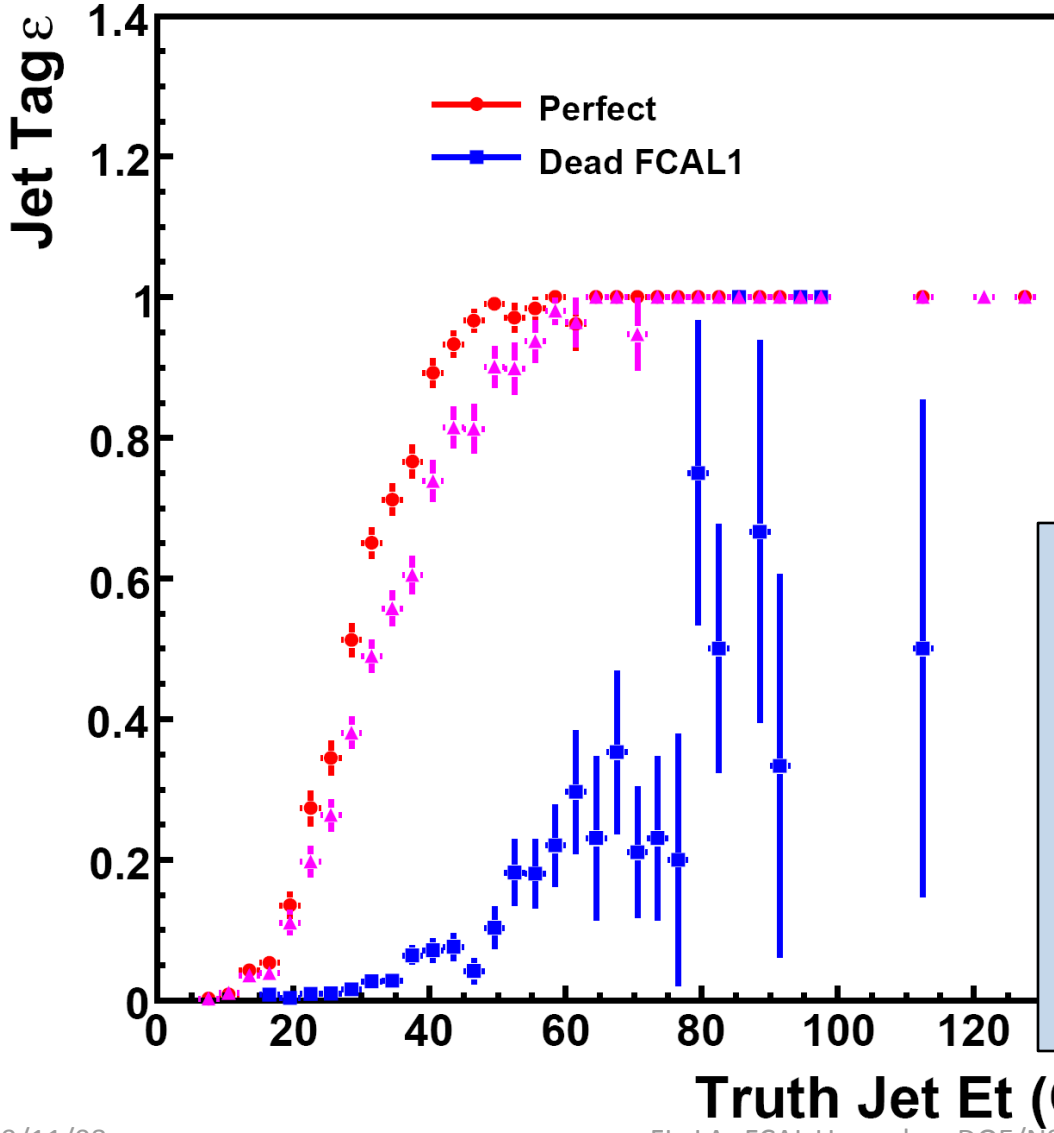
Color coded maps:

GREEN: normally operating

YELLOW: Stability limit region.

RED: unstable. No signal and energy reconstruction

Physics Impact of a non functioning FCAL



- Jet tagging in the forward region can be used to enhance S/B in some processes (e.g. events involving WW fusion)

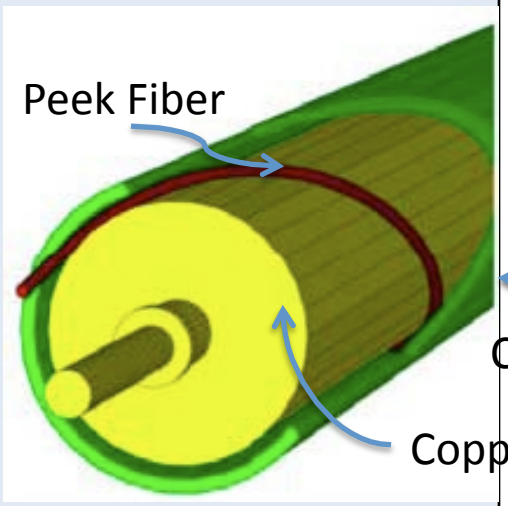
- Preliminary simulations by C. Oram et al:
- http://indico.cern.ch/conferenceDisplay.py?confId=24195
- Dead FCal 1 should be rejected as an option.

FCAL1 Upgrade Options

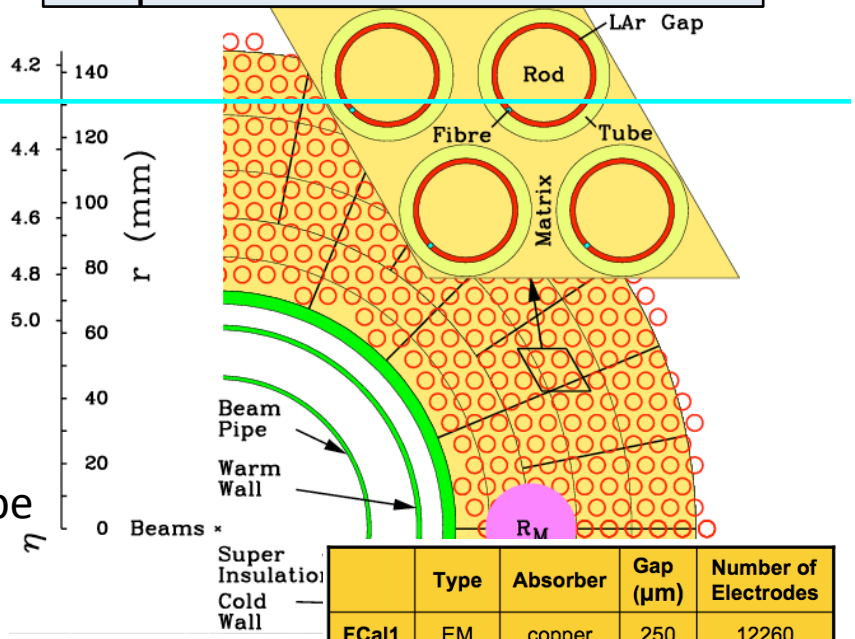
- Two alternatives:

1. Design a newly re-optimized FCAL1

2. …



- Optimize tube geometry to eliminate space charge effects (smaller gaps)
- Engineer an inner cooling loop to intercept the heat and avoid risk of boiling
- Redesign HV bias distribution network and protection resistor.

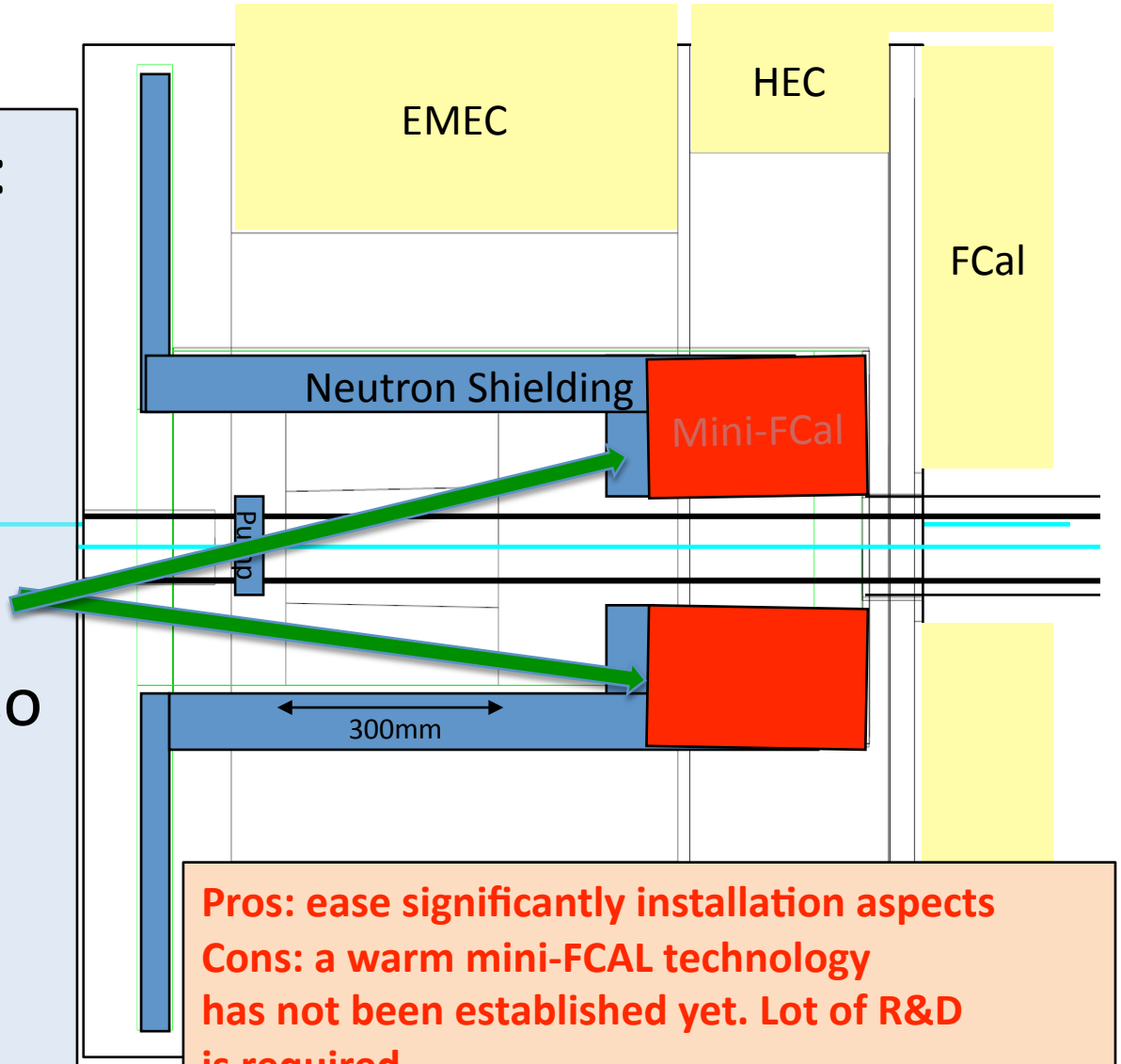


	Type	Absorber	Gap (µm)	Number of Electrodes
FCal1	EM	copper	250	12260
FCal2	HAD	tungsten	375	10200
FCal3	HAD	tungsten	500	8224

FCAL1 Upgrade Options

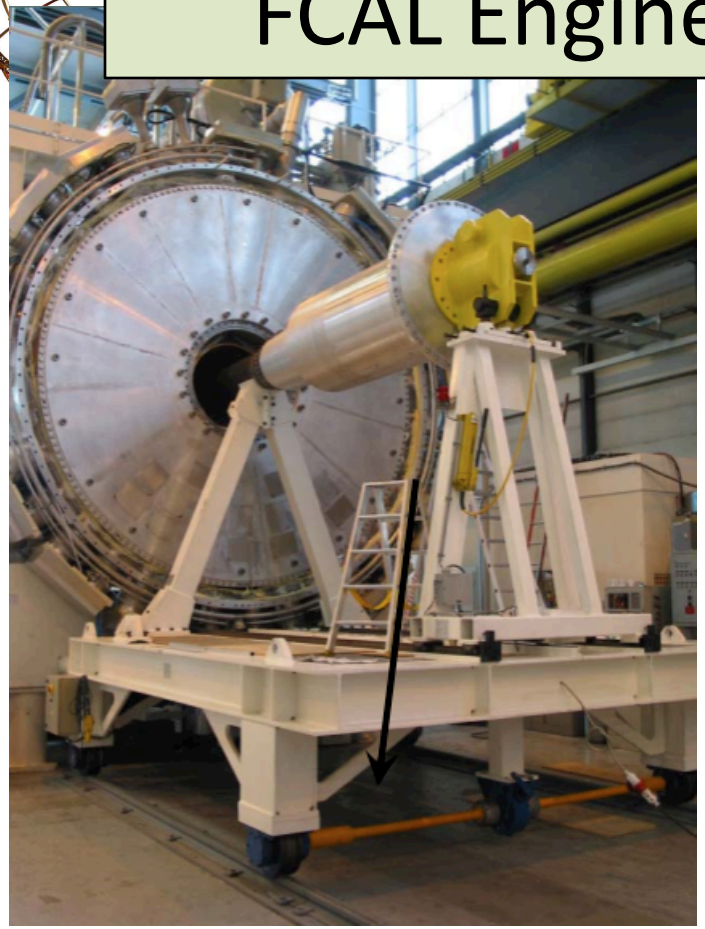
- Two alternatives:

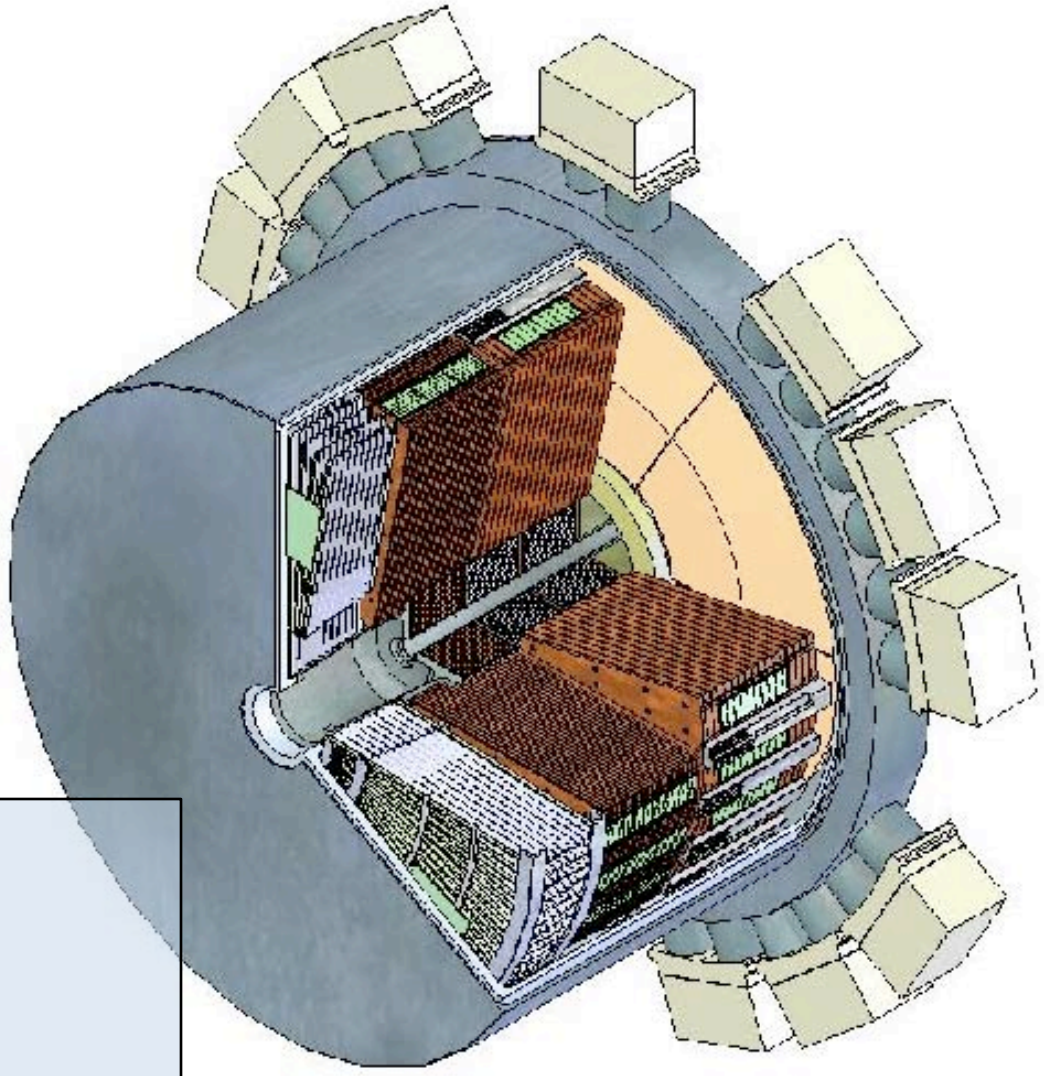
1. Design a newly re-optimized FCAL1
2. Install a warm mini-FCAL in front of FCAL1 so that the latter becomes a tail catcher for EM showers



Pros: ease significantly installation aspects
Cons: a warm mini-FCAL technology has not been established yet. Lot of R&D is required

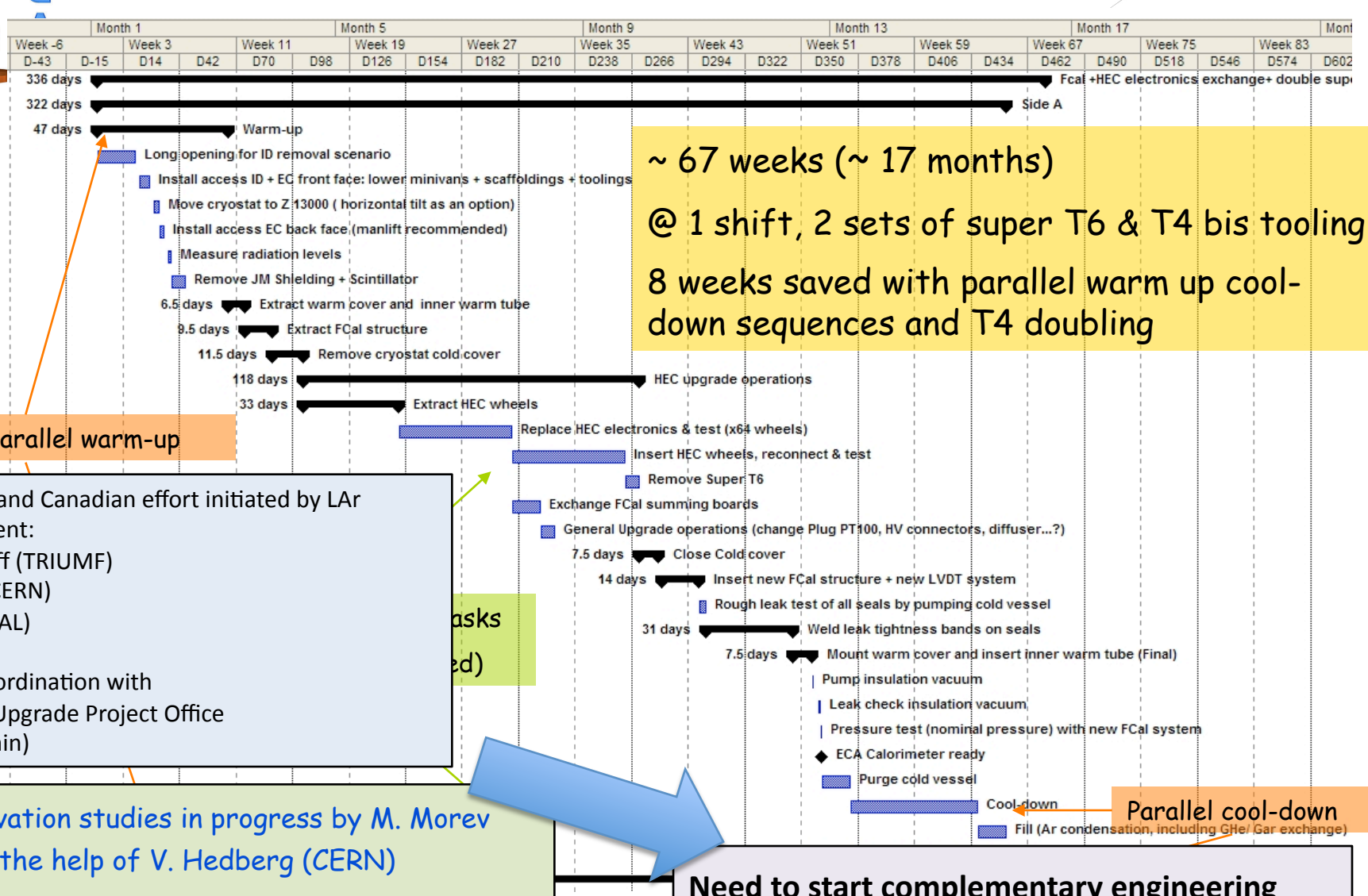
FCAL Engineering Studies Needed!





Severe Constraints for installation:
- **Activation**
- **Limited Time**
- **Limited Access**
- **Tooling**
- **Conflicts with upgrade of other subsystems (ID and muon)**

FCAL Engineering Studies Needed!



~ 67 weeks (~ 17 months)

@ 1 shift, 2 sets of super T6 & T4 bis tooling

8 weeks saved with parallel warm up cool-down sequences and T4 doubling

Parallel warm-up

Parallel cool-down

European and Canadian effort initiated by LAr management:
R. Langstaff (TRIUMF)
C. Fabre (CERN)
A. Falou (LAL)

Now in coordination with
The Atlas Upgrade Project Office
(R. Villuemin)

+ … Activation studies in progress by M. Morev with the help of V. Hedberg (CERN)

Need to start complementary engineering studies (i.e. detector specific) NOW

Atlas - LAr Strategy

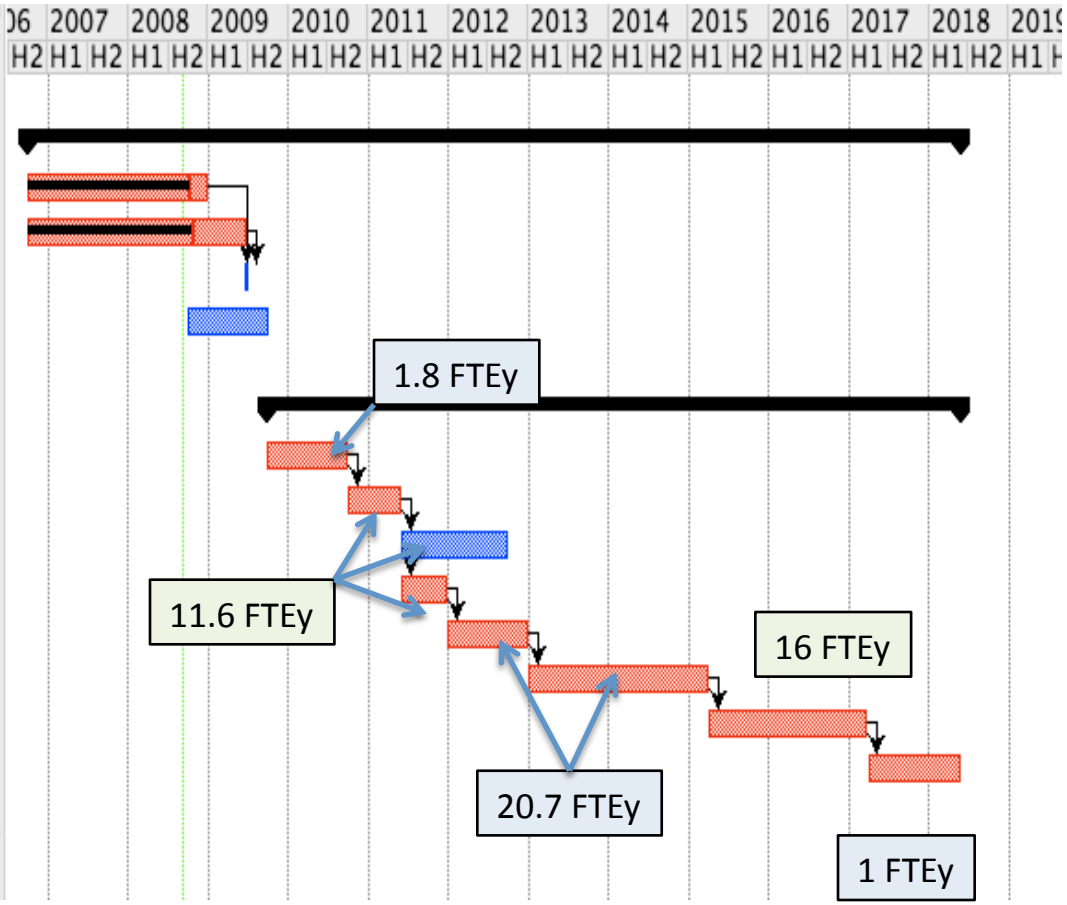
- The FCAL will not operate @ sLHC (Phase-II).
- The only possible upgrade is by the long shutdown (2016/2017)
- Need more studies to address criticality of the FCAL issues for Phase-I
  - Calculations are based on MC with significant variation between min. bias generators
  - Need to collect data (end of 2008/mid-late 2009)
- Scope of the project extends for several years
  - "Lessons" from the original construction project (design through installation onto the end-cap cryostat)
- Need to develop both options in parallel… **STARTING NOW…**
  - Detector R&D for the "warm"-option
  - Design and detailed engineering studies for a cold FCAL1 replacement as integral part of a construction project and of the decision making process
- Tradeoff between technology challenges vs. ease of installation/ integration inside the Atlas detector
- Decision and ready to start production in 2011

Summary: FCAL Upgrade Goals and US Deliverables

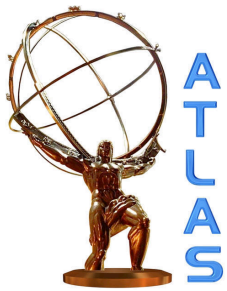
- Maintain leadership role in Atlas for the Forward Calorimetry
  - Developing tools and all preparatory engineering studies to be ready to launch replacement
  - Defining detailed design of an upgraded "cold" FCAL1 detector
  - **Request of a Phase-I construction project for a cold FCAL1 upgrade:**
    - **Engineering resources and manpower for design of a newly optimized FCAL1 module, new services (cooling) and a new HV distribution scheme**
- **In case a "cold" FCAL upgrade will be decided (end 2011):**
  - **Assume direct responsibility in construction/assembly of the FCAL1**
  - **Share responsibility during assembly and installation phases at CERN**
  - **Total: 51.1 FTE-yrs (2010-2018), 8.1M**
    - **See Howard's summary for detailed resource/manpower needs**
- If the FCAL will be "warm" the US responsibilities and contributions have to be understood and clarified

FCAL Upgrade Construction Project

		Name	Duration	Start	Finish
2		FCAL R&D Simulations, Testbe	3,044 day...	10/2/06...	5/31/18
3		R&D Studies	588 days	10/2/06...	12/31/08
4		Protvino Testbeam	717 days	10/2/06...	6/30/09
5		R&D Completion	0 days	6/30/09...	6/30/09
6		Simulations	262 days?	10/1/08...	10/1/09
8		FCAL1 Construction Project	2,261 day...	10/1/09...	5/31/18
9		Preliminary Design	261 days?	10/1/09...	9/30/10
10		Proto/Pre-Prod.	174 days?	10/1/10...	6/1/11 5
11		Beam tests on pre-prod modu	347 days?	6/2/11 ...	9/28/12
12		Final Design	152 days?	6/2/11 ...	12/30/11
13		Part Procurement	261 days?	1/2/12 ...	12/31/12
14		Module Production	587 days?	1/1/13 ...	4/1/15 5
15		Assembly	522 days?	4/2/15 ...	3/31/17
16		Installation	304 days?	4/3/17 ...	5/31/18

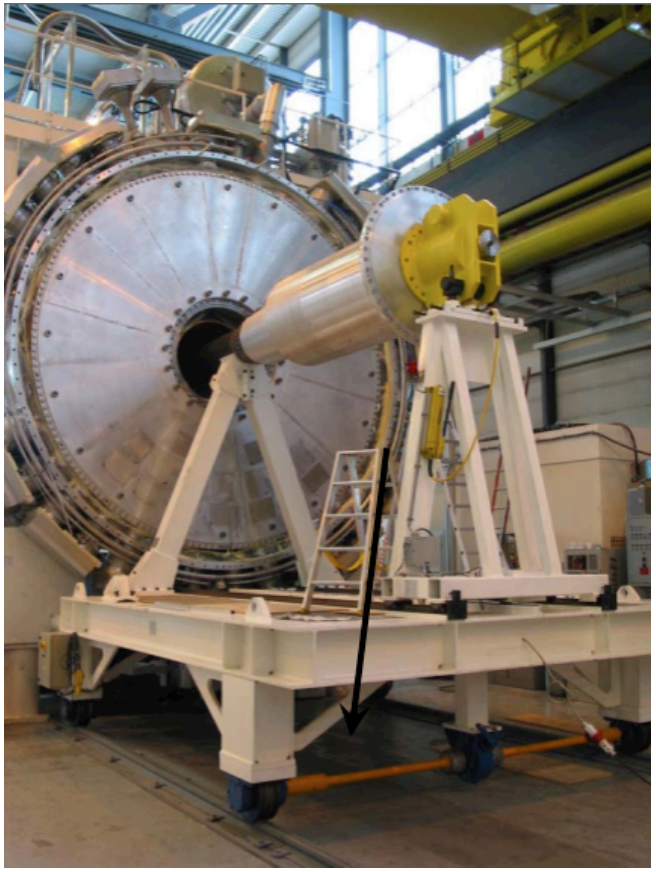


Schedule and Resources

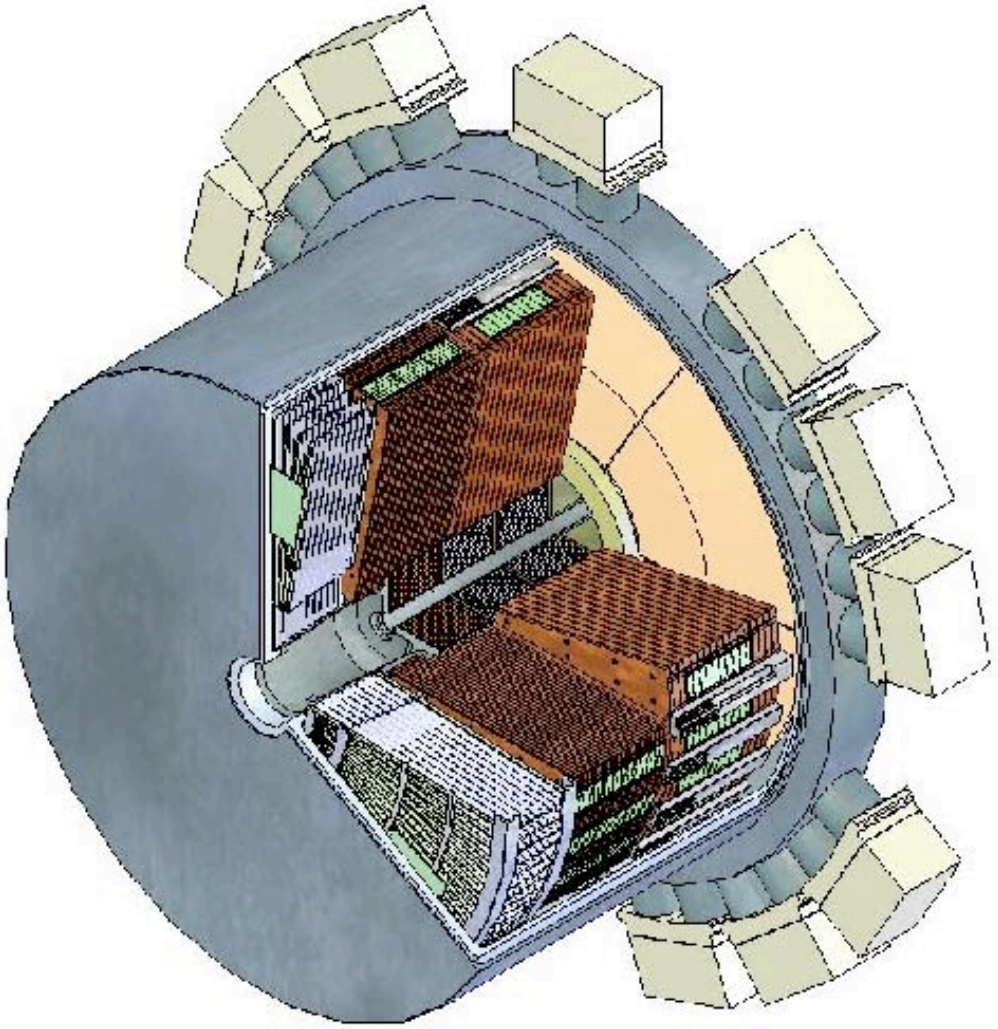


BROOKHAVEN NATIONAL LABORATORY

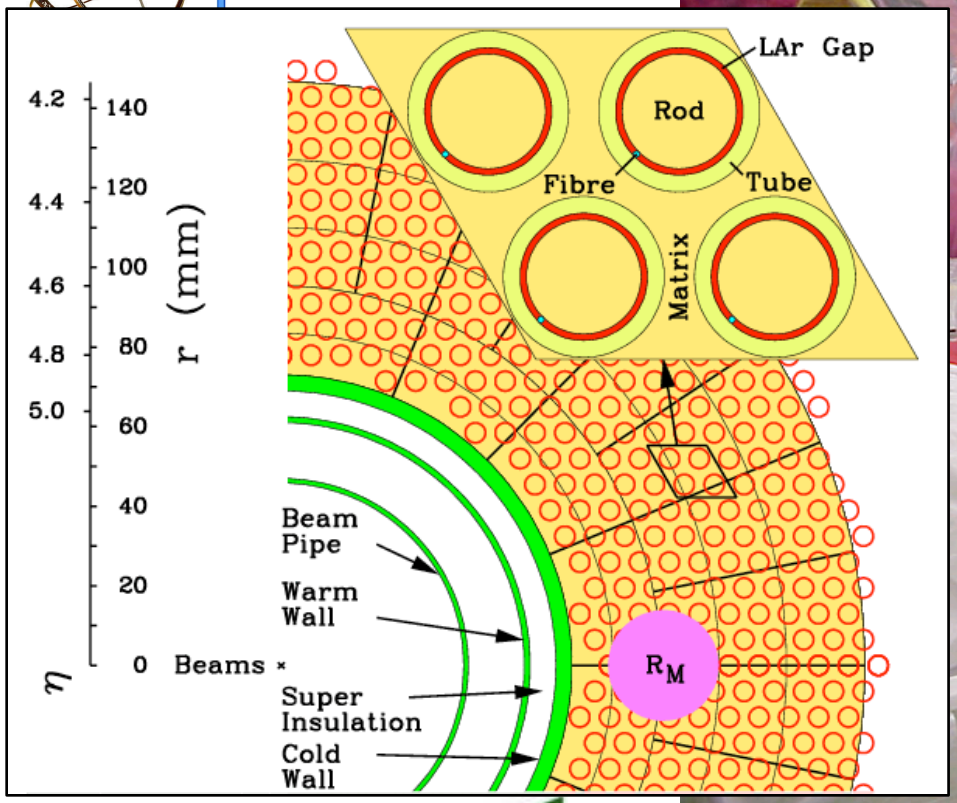
Backup Slides

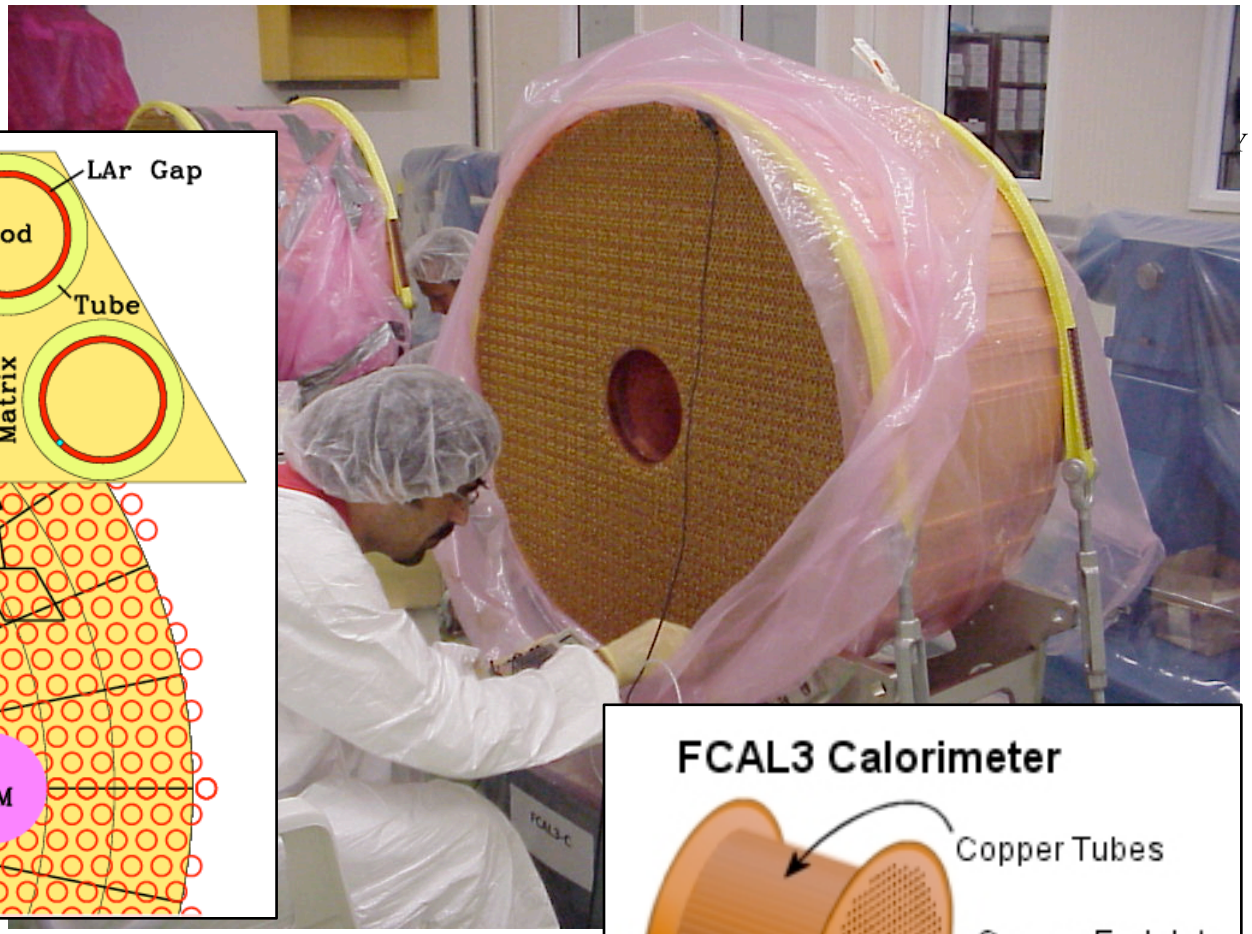


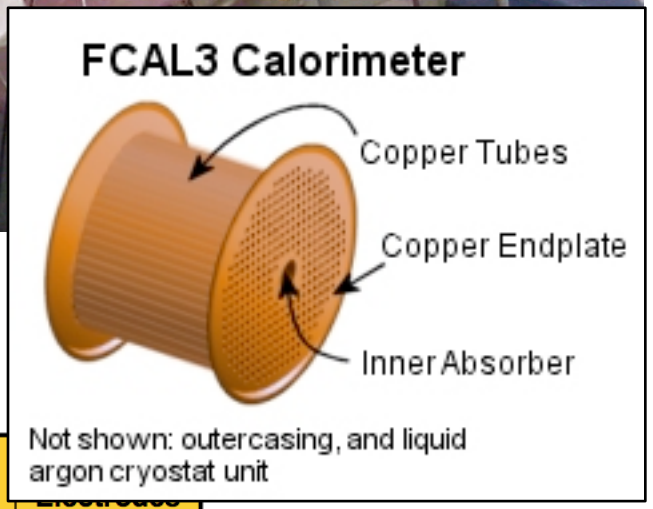
BROOKHAVEN
NATIONAL LABORATORY

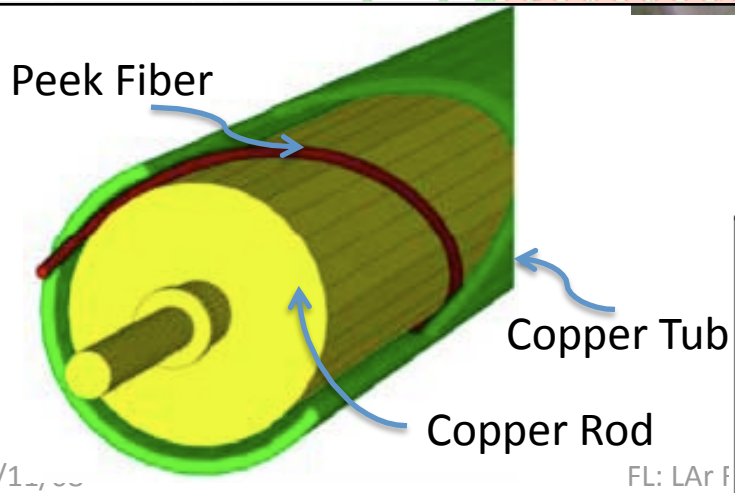


Shielding Pug
FCAL2,
FCAL3:
HAD
Support Tube
Forward Cone
FCAL1: EM

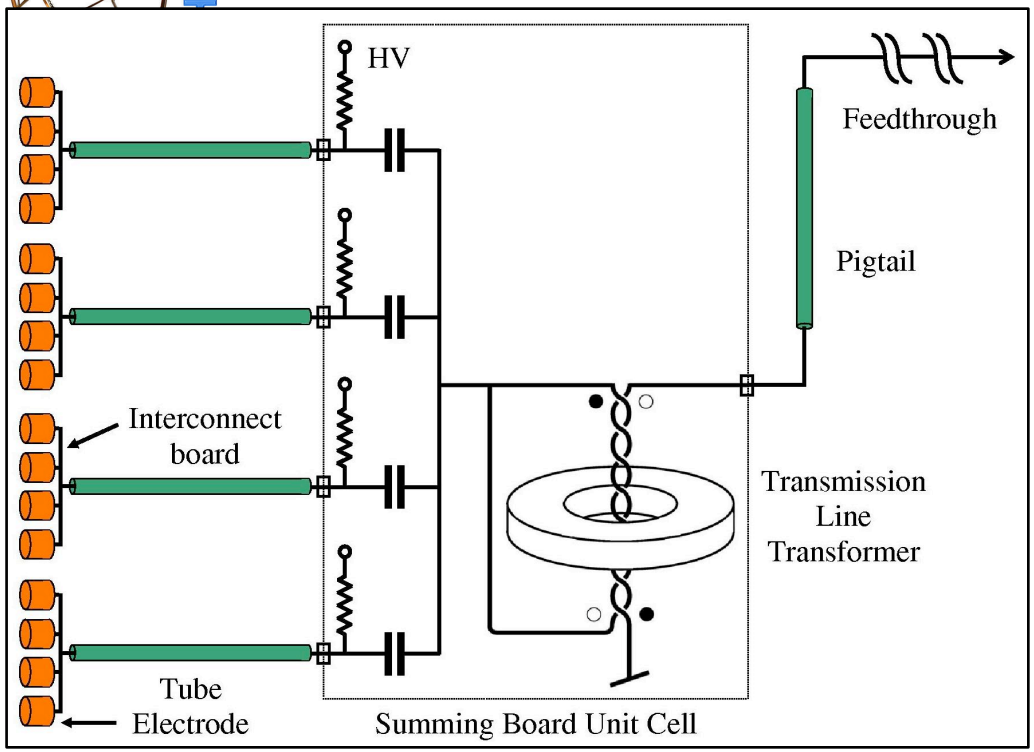


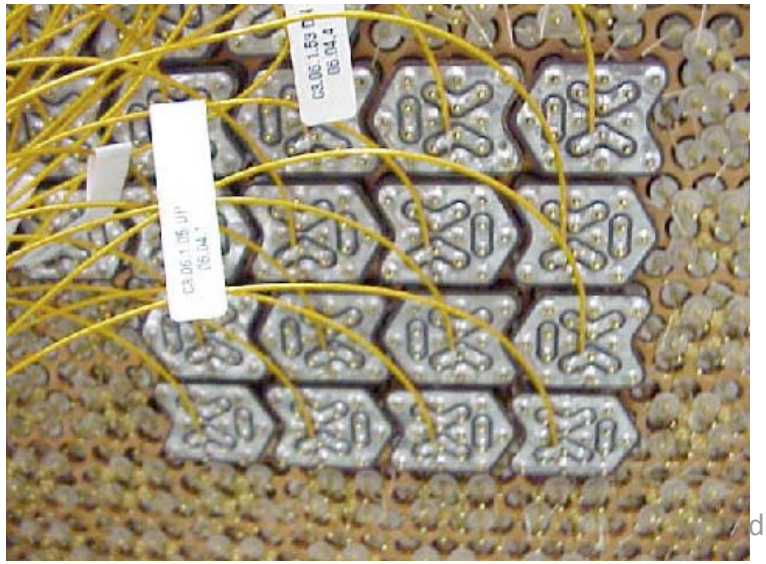






	Type	Absorber	Gap (μm)	
FCal1	EM	copper	250	12260
FCal2	HAD	tungsten	375	10200
FCal3	HAD	tungsten	500	8224





- Electrodes ganged together at module face:
  - 4,6 and 9 for FCAL1,2,3
- For most channels, 4 (adjacent) groups are summed on special SB PCBs in LAr
  - Provides adequate granularity
  - Reduced number of readout channels and FT penetrations
- Matching transformer and transmission line coupling to the "regular" Front-End Boards (preamp/shaper/ SCA)

Super T6 for HEC wheels extraction → bv Rov Lanastaff